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INSTRUCTIONS AT LARGE,

For the USE of

HADLEY's QUADRANT:

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Wherein are contained the

PRINCIPLES on which that moſt ingeniouſly contrived, and uſeful Inſtrument is conſtructed;

Together with a

DESCRIPTION and USE of VERNIER's, erroneouſly called NONIUS's Diviſions.

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BRITISH MUSEUM

INSTRUCTIONS

FOR THE

Uſe of HADLEY's Quadrant, &c.

THIS moſt curious Inſtrument was invented by *J. Hadley*, Eſq; ſome Years ago, and is now ſo well known as to need no Recommendation, and its Uſefulneſs ſo conſpicuous and great, that it muſt be ranked amongſt the moſt conſiderable Improvements in the Practice of *Navigation.*

The peculiar Advantages which this Inſtrument is poſſeſſed of, in Preference to any other adapted to the ſame Purpoſe, are theſe following, *viz.*

Firſt. The Obſerver is not liable to any Interruption, or Inaccuracy by the Ship's Motion, which is common to all other Inſtruments now in Uſe, and is ſo prejudicial, eſpecially in rough and hollow Seas, that no Dependance can be had upon Obſervations then taken.

Secondly. The Sun by Reflection appears at the ſame Diſtance as the Horizon; hence, one Poſition of the Eye ſerves to look at the Sun and Horizon, ſo as to ſee them perfectly, and diſtinct together.

Thirdly. It admits of more frequent Obſervations than any other that requires an Horizon; for if the Body of the Sun can but be diſcerned through the Clouds, it will appear juſt the ſame by Reflection; and on the other Hand, when he is too glaring for the naked Eye, the *Skreens* aſſiſt you to make a perfect Obſervation.

Fourthly. The Sun's Altitude may be taken with more Accuracy when he is near the Zenith, eſpecially by a leſs expert Obſerver.

Fifthly. It hath ſuperior Advantage in obſerving by the Stars, during Morning and Evening Twilight, and on Moon-light Nights.

Sixthly. The Glaſſes may eaſily be adjuſted, and a Stranger to Practice, may inſtantly come into the Knowledge of its Uſe and Application, to render which as plain as poſſible is the chief Purport of this little Treatiſe.

But, as ſome of the ingenious Mariners may be deſirous to underſtand the Principles upon which this noble Inſtrument is conſtructed, I ſhall, in the firſt Place, lay down the Theory in the cleareſt Manner, and by Diagrams ſuited to the Conſtruction and Form of this Quadrantal-Octant.

And for this Purpoſe, it will be abſolutely neceſſary to have a clear Idea of the Poſition of the Glaſſes, and Courſe of the Rays, when the Index ſtands at the Beginning of the Diviſions on the Arch, as thoſe are repreſented in.

Plate 2. *Fig.* 1. This Scheme repreſents the Glaſſes in a parallel Poſition as they ſhould be when the Index ſtands at (*o*), that is, at the Beginning of the Diviſions, if the Object is at a very great Diſtance; exhibiting at the ſame Time the Courſe of a direct and reflected Ray both of them coincident at the Eye.

The two reflecting Mirrors are repreſented in this Figure at I and *i* drawn parallel to each other, and *ri* E repreſents a Ray of Light proceeding from a very diſtant Object, which paſſing through the Glaſs *i*, is tranſmitted in a ſtreight Line to the Eye, which is ſuppoſed to be at E.

The Line RI ſhews the Courſe of a Ray of Light proceeding from the ſame remote Object, which falling on the Glaſs I is reflected back in the Line I*i* to the ſmall Mirror or Glaſs *i*; by which it is again reflected in the Line *i*E; and thus it comes to the Eye in the ſame Line as the direct Ray *ri* E. Therefore the Object ſeen by Reflection will coincide with the ſame Object ſeen by direct Viſion.

DEMONSTRATION.

DEMONSTRATION.

The Proof hereof is eſtabliſhed on a known Principle in Optics, *viz.* that the *Angle of Incidence is always equal to the Angle of Reflection.* The *Angle of Incidence* is that which is formed between the Ray that ſtrikes on the Surface of the Mirror, and a Line that is perpendicular to the Mirror at the ſame Point. The *Angle of Reflection*, on the contrary, is that contained between the ſame perpendicular Line and the Ray which is reflected from the Mirror, on the other Side the Perpendicular.

Thus R I is the *incident Ray*, and L I being perpendicular to the Mirror at the Point where the Ray ſtrikes the Angle R I L is the *Angle of Incidence*, and I *i* being the reflected Ray on the other Side the Perpendicular, it makes the *Angle of Reflection* L I *i* equal to R I L. By the ſame Rule I *i* being an incident Ray on the Mirror *i*, and *i l* being the Perpendicular, the Angle I *i l* will be equal to *l i* E. But the Line I *i* being drawn between two Parallels (as the Perpendiculars to the two Mirrors are ſuppoſed to be) the alternate Angles hereby made with thoſe Parallels are equal; that is, L I *i* muſt be equal to I *i l*, and therefore the double of theſe muſt alſo be equal; that is, R I *i* muſt be equal to I *i* E, and conſequently R I muſt be parallel to *i* E. Q. E. D.

COROLLARY. Hence it follows, that the Lines R I and *r i*, being produced to a very great Diſtance, will meet, as to Senſe, at the ſame Point, and the Object ſeen by Reflection will be the ſame as that ſeen by direct Viſion through the tranſparent Part of the Horizon Glaſs. Nor is it material what Part of the Glaſs the Object is ſeen through; for as the parallel Direction of the Lines depends upon the Paralleliſm of the Glaſſes, therefore the Object will appear ſingle as long as it is kept in Sight through any Part of the Glaſs.

Having now conſidered the Courſe of the Rays in the parallel Poſition of the Glaſſes, it will be neceſſary in the next Place to examine what will be the Effects of turning one of the Glaſſes out of a Parallel, into an oblique Poſition, like unto that repreſented in the ſecond Diagram.

Plate 2. *Fig.* 2. is to ſhew the Courſe of the *reflected Ray* in this oblique Situation of the Glaſſes.

In this Figure L I is to ſhew the Poſition in which the Perpendicular to the Glaſs I ſtood in the former Figure, where the Glaſſes were ſuppoſed to be parallel to each other. But now the Index is turned from that Poſition, and the Glaſs being turned with it, the Perpendicular to its Surface becomes K I; whence K I L ſhews the Angle of its Motion from its firſt Poſition. The Line R I ſhews the *incident Ray*, which in order to its being reflected in the Line I *i* muſt make an equal Angle with the Perpendicular K I; that is, the Angle R I K muſt be equal to the Angle K I *i*, but this laſt Angle is greater than L I *i*, which was the correſponding Angle in the former Figure, by the Angle K I L, and therefore its double R I *i*, muſt be greater than its correſponding Angle in the Figure, by twice the Angle K I L; whence it appears that the Object ſeen by Reflection in a Coincidence with that ſeen by direct Viſion in the Line E *i r*, will ſubtend an Angle equal to twice the Angle K I L, that is, equal to twice the Quantity of the angular Motion of the Glaſs and Index.

Hence it appears that when the Index is moved half a Degree from its firſt Poſition, were the Glaſſes were reduced to a Paralleliſm, the object ſeen by Reflection, which will there ſeem to coincide with that ſeen by direct Viſion, will in Reality be ſo far from it as to ſubtend an Angle of one whole Degree: So that half Degrees on the Arch will anſwer to whole ones in the Angle obſerved.

For which Reaſon an Arch of 45 Degrees, is in this Inſtrument divided into 90 Parts, and are eſtimated as Degrees, becauſe they correſpond to ſo many Degrees in Obſervation.

In the firſt Diagram the Glaſſes are ſuppoſed parallel to each other, becauſe the Object by which they were fixed, and from which an Angle was to be meaſured to ſome other Object, was ſuppoſed to be at a very great Diſtance; but if the Object was near, the Glaſſes would be a little inclined; nevertheleſs if the Index be brought to the Beginning of the Diviſions on the Arch (as in *Plate* 1. *Fig.* 1.) and the Glaſſes be ſo fixed as to ſhew the Object ſingle, then the Angle made between that and a ſecond Object will be truly given by moving the Index forward on the Arch, until the ſecond Object ſeen by Reflection appears to coincide with that ſeen by direct Viſion; becauſe the Angle ſubtended by the Objects will be equal to double the angular Motion of the Index, and therefore the Number of Degrees on the Arch will truly expreſs the Angle between the Objects as ſubtended from the Center of the Index Glaſs.

Hence it evidently appears from what has been ſaid, that if the Arch be truly graduated, and the Glaſſes perfect parallel Planes, there can be no Error in taking an Angle with this Inſtrument: But all other Inſtruments are ſubject to various Errors, either from their Conſtruction, or being liable to warp, or from the Motion of the Ship, *&c.* whereas there is a Conveniency in this to adjuſt the Glaſſes, and by that Means the Obſervation is rendered certain.

The Theory of this Quadrant being once rightly underſtood, there will be but very little Difficulty in comprehending its Uſe; and though there are ſeveral Pages filled with Directions, ſo that every Particular might be made as clear as poſſible to the meaneſt Capacity, yet, to a Perſon who has a right Notion of the Theory, the following Precepts will be ſo far from being a Load upon his Memory, that they will rather appear as Illuſtrations of the Ideas which he has already acquired of the Inſtrument.

Before we proceed to lay down Directions concerning the Uſe hereof, it will be very neceſſary to give a Deſcription of its ſeveral Parts or Members.

This Inſtrument conſiſts of theſe ſeveral Parts, *viz.*

1. An Octant, or one eighth Part of a Circle.
2. The Index.
3. The Mirror, or large Speculum.
4. The two Horizon Glaſſes, or Vanes for the fore and back Obſervation.
5. The two Skreens, for checking or obſcuring the Sun's Rays.
6. The two Sight Vanes, for the fore and back Obſervation.

1. *Of the* OCTANT.

This is one eighth Part of a Circle, or 45 Degrees, (ſee both Figures in *Plate* 1.) but the Arch A C is divided into ninety equal Parts, called Degrees, which are diſtinguiſhed by Lines drawn through the concentric Circles; the other three Subdiviſions of 20 Minutes each, are pointed out by Lines drawn through the two outward concentric Circles only; ſometimes there are ſix of theſe Subdiviſions, of 10 Minutes each, and theſe laſt are again ſubdivided into Minutes ſometimes by a Diagonal, and ſometimes by a Nonius or *Vernier*'s Diviſion: Although this Inſtrument is but an Octant, and its large Diviſions no more than half Degrees, yet from its Conſtruction, and the Nature of Reflection, it anſwers to as many whole Degrees, as has been demonſtrated in the preceeding Pages; whence it is in Effect a Quadrant.

2. *Of the* INDEX.

The Index is a flat Ruler (D) moveable about the Center (I), and marks the Diviſions graduated on the Arch AC: On the back Side of the Arch there turns up a Piece of Braſs with a Skrew in it, which ſerves to faſten and ſecure the Index againſt any Diviſion you deſire.

3. *Of the* MIRROR *or large* SPECULUM.

This is a Piece of Glaſs quickſilvered, fixed in a braſs Box over the Center (I), and perpendicular to the Plane of the Inſtrument, and alters its Direction as the Index ſlides along the Arch; it receives the firſt Image of the Sun, or other Object, and reflects it to either of the Horizon Glaſſes, F or B, accordingly as you are about to take a fore or backward Obſervation.

4. *Of the* HORIZON GLASSES.

That (F), for a forward Obſervation hath that Part quickſilvered which is next the Plane of the Octant and receives the Reflection from the Index-Glaſs, or large Speculum (I), and reflects it back to the Eye at E, the upper Part is left tranſparent to give Light by direct Viſion, for by this Means you ſee the Horizon through it, at the ſame Time that you ſee the Sun by Reflection.

The other (B) for a backward Obſervation is ſilvered at both Ends, in order to receive the Image of the Object, as before, by Reflection; and, in the Middle thereof is a tranſparent Slit, through which the Horizon is ſeen by direct Viſion, as in the former.

Both theſe Glaſſes are ſo mounted, as to have their Poſitions varied, by the Aſſiſtance of braſs Levers on the back Side of the Inſtrument, ſhould the Wood-work at any Time ſhrink or warp.

5. *Of the two* SKREENS.

Theſe are two reddiſh coloured Glaſſes (H), one of them of a deeper Colour than the other, and ſerve to abſorb the Rays of the Sun, and preſerve the Eye, during the Time of Obſervation, and may be ſhifted, and made Uſe of in either a fore or back Obſervation;

either of them or both may be uſed according to the Strength of the Sun's Rays; or both may be rejected in gloomy Weather.

6. *Of the two* SIGHT VANES.

That (G) for a fore Obſervation hath two Holes to direct the Sight parallel to the Plane of the Quadrant; one of them exactly at the Height of the quickſilvered Edge of the Horizon Vane from the Plane of the Inſtrument; the other is placed ſomewhat higher, in order to direct the Sight to the Middle of the tranſparent Part of the ſaid Glaſs or Vane.

That (E) for a back Obſervation hath but one Hole which is placed in a Line with the Middle of the tranſparent Part or Slit of the back Horizon Vane, B.

To adjuſt the GLASSES.

The Altitude of any Object when taken by this Inſtrument is determined by the Inclination of the Planes or Surfaces of the Glaſſes one to another, *viz.* by F and I in the fore Obſervation, and by B and I in the back, as has been ſhewn in the Theory; whence it follows, that when the Index is fixed or ſet to the Beginning of the Degrees or Diviſions on the Arch, the Horizon ſeen by Reflection ought to coincide with the ſame ſeen by direct Viſion, or in other Words, they ſhould appear as one; and to know whether this is the Caſe, in the fore Obſervation, ſet the Index (D) to the Beginning of the Degrees, as above directed, by bringing it cloſe to the Button (*Plate* 1. *Fig.* 1.) which will ſtop it at that Point; then hold the Inſtrument upright, and look through the lower Hole in the Sight Vane (G), and alſo through the tranſparent Part of the Horizon Glaſs (F) obſerving whether the Edge of the Sea ſeen in the quickſilvered Part by Reflection, joins in the ſame ſtreight Line with that ſeen through the un-

unquickſilvered Part; if not, that is, if they appear broken or double, bring them into one right Line, by gently turning the Leaver belonging to the Glaſs, on the back of the Inſtrument, and there fix it by the Help of the Skrew which works through the Center of the Leaver.

As the fore Obſervation gives any Angle from 0 to 90, or a whole Quadrant; ſo the back Obſervation gives any Angle from 90 to 180, ſo that in fact it produces the Quadrant to a Semicircle; for as the Obſerver in the fore Obſervation turns his Face to the Sun, and brings it down by Reflection to the Horizon directly thereunder, which never exceeds 90 Degrees; ſo on the contrary, in the back Obſervation he turns his Back to the Sun, and brings it by Reflection round the Zenith, unto that Part of the Horizon oppoſite thereto, which will always be greater than 90 Degrees: It is true indeed that the ſame Diviſions and the ſame Numbers ſerve to expreſs the Altitude in the back Obſervation, as well as in the fore, but theſe muſt be underſtood to expreſs the Supplement to a Semicircle.

Seeing then that the back Obſervation takes all Angles from a Quadrant to a Semicircle, or 180 Degrees, it is evident that when the Index ſtands at the Beginning of the Diviſions, the Angle will be extended to 180 Degrees compleat; wherefore, if the Glaſſes are truly fixed, the Object ſeen by Reflection, will be diametrically oppoſite to that ſeen by direct Viſion.

Now if the viſible Horizon was not lower than the true Horizon, occaſioned by the Height of the Obſerver's Eye above the Surface of the Water, hereafter explained, it would follow that the Horizon behind the Obſerver ſeen by Reflection would coincide with that Part before him ſeen by direct Viſion, becauſe he would ſtand in a Diameter, or from Horizon to Horizon would be a compleat Semicircle. But as there is the Dip, which muſt be allowed for both Ways, the Angle or Arch contained from one Part of the Horizon to its oppoſite muſt be more than 180 Degrees by double the

Dip of the Horizon: Wherefore to adjuſt the Glaſſes for the back Obſervation, let the Obſerver turn down the Button that ſtops the Index D, and move it beyond the o in the Diviſions (as there are always a few ſupernumerary for that Purpoſe) as many Minutes as are equal to double the Dip, and ſkrewing the Index faſt there, bring the Edge of the Sea ſeen by Reflection, to coincide with the Edge ſeen by direct Viſion through the tranſparent Slit in the Horizon Glaſs, by the Help of its proper Leaver, on the Back of the Inſtrument, as before directed in the Adjuſtment for a fore Obſervation; only take Care that the Horizon behind does not croſs *that* before you, for this will be a Proof that your Quadrant is not held upright, and thereby your Rectification would be rendered uncertain; but hold it ſo, that both Horizons may lie one in the other, as one Line.

During this Operation you will perceive that the Horizon behind you will be inverted by the Reflection, that is, the Water will appear above and the Sky below, whence it is plain that the Sun will be inverted alſo, when you take his Altitude this Way; that is, the Sun's upper Edge will come firſt in Contact with the Horizon, inſtead of his lower Edge, which touches firſt in the fore Obſervation: Wherefore, as you add 16 Minutes in the fore Obſervation to obtain the Altitude of the Sun's Center, ſo you muſt here on the contrary ſubtract the ſame, becauſe you have your Altitude from the upper Edge.

In taking a fore Obſervation the Dip of the Horizon is to be ſubtracted from the Altitude, but in the back Obſervation it is to be added, unleſs you ſhall think fit to adjuſt the back Horizon Glaſs in the Manner, following, *viz.* Fix the Index cloſe to the Button, and proceed as heretofore directed in the fore Obſervation, in Conſequence whereof you muſt ſubtract the Dip from the given Altitude, which is a more eaſy and natural Way, and equally as true.

Another

Another Method of adjuſting the Horizon Glaſs for a back Obſervation, when you have a clear Horizon both under the Sun, and oppoſite thereto, ſo that you may be able to take the Altitude both Ways.

Begin firſt with the fore Obſervation, and as ſoon as you have obſerved the lower Edge of the Sun to touch the Horizon, turn yourſelf about, to take the back Obſervation, keeping the Index (D) in its Place, and if you find that the Sun's apparent upper Edge (which is really its lower Edge, on Account of its being inverted by Reflection) exactly coincides with the Horizon, you may then pronounce your Glaſs is truly fixed; if not, turn your Horizon, by its proper Leaver, and ſet it right. If the Sun ſhould be riſing or falling pretty quick while you are rectifying the Glaſs, it will be neceſſary to repeat your fore and back Obſervation two or three Times, leſt the Sun ſhould change its Altitude during the intermediate Time: But if the Sun be near the Meridian, the Variation will be inconſiderable; and this Method of fixing the back Obſervation-Glaſs is preferable to all others, as being by much the eaſieſt and leaſt liable to Error; another Advantage ariſes by this Way of Adjuſtment, *viz.* That all the three Corrections are to be allowed the ſame Way as in the fore Obſervation.

As the chief Uſe of the back Obſervation is for taking Altitudes when the fore Horizon happens to be obſcured, it is evident that at the Time it is moſt wanted, it will be impoſſible to fix it, therefore it ſhould always be kept ready, for which Reaſon it is adviſeable that the Mariner make this Adjuſtment at the firſt Opportunity he meets with, after he gets on board, and to repeat theſe double Obſervations ſo frequently, as to have at laſt a perfect Dependance thereupon, for it may happen to be of great Conſequence upon certain Occaſions.

Theſe Rules and Cautions for fixing the Glaſſes may appear to ſome Perſons, at firſt Sight, as intricate, and arguing ſome Imperfection in the Inſtrument; but it it is ſo far from Imperfection, that is really a very great Excellency, as hereby it is capable of being adjuſted at Pleaſure: For as all Inſtruments are liable to warp more or leſs, beſides many other Defects that may proceed from Want of Care in the Workman that firſt put them together, from whence many conſiderable Errors may ariſe; but here, if the Graduations are juſt, and the Glaſſes true Planes, all Defects are preſently rectified, nor is it poſſible to vary either Northward or Southward, as other Inſtruments often do.

Of the DIP *of the* HORIZON.

I have already obſerved, that to obtain the Altitude of the Sun's Center, you muſt add 16 Minutes for his mean Semidiameter, when you take his Altitude from the lower Limb, in a fore Obſervation; and ſubtract 16 Minutes therefrom in a back Obſervation; but beſides this, in Order to compleat the Accuracy of your Altitude, two additional Corrections muſt be made; one of theſe ariſes by Reaſon of Refraction, occaſioned (in ſmall Altitudes eſpecially) by the Hazineſs of the Atmoſphere; the other, on Account of the Obſerver's Eye being raiſed above the Surface of the Sea, for then the Plane paſſing through the Center of his Eye, parallel to the Horizon, will be above the true Horizon, ſo that the Altitude of the Sun, taken by this Octant, or any other Inſtrument, will hereby become as much greater than his real Altitude, as the Plane of that apparent Horizon is below that of the real one; and therefore that Difference being eſtimated, muſt be taken from the obſerved Altitude, in order to obtain the real or true Altitude; and as the Height of the Obſerver's Eye is more or leſs removed from the Surface of the Sea, according to the Rate or Magnitude of the Ship, or Elevation of the Place where the Obſervation is taken, ſo the ſaid Difference becomes more or leſs accordingly.

In

In *Plate* 2. *Fig.* 3. Let the Circle SONH repreſent the terraqueous Globe, of which T is the Center, S is the upper Surface of the Sea, E the Obſerver's Eye, then will the Line HEA repreſent the true Horizon, but E *t* B being drawn to touch the Circle at *t*, that Line will be the viſible Horizon, becauſe in that Line the Obſerver ſees the Boundary or Limits of the Sky and Water.

But the true Horizon is HEA as I have above ſaid, as being perpendicular to the Plomb Line E S, therefore the Angle *t* E H is the Difference between the true and viſible Horizon, which is commonly called the Dip of the Horizon; and this muſt be ſubtracted from the Sun's Altitude obſerved.

Thoſe who are acquainted with the firſt Rudiments of Geometry and Trigonometry, will be able to find the Quantity of the Angle of the Dip for any given Height of the Eye above the Surface of the Sea, provided they know the Earth's Semidiameter nearly; but for the Sake of ſuch who are leſs ſkilled in theſe Affairs, here follows a Table of Angles anſwerable to different Heights of the Eye above the Surface of the Sea.

The Eye above the Surface of the Sea in Feet.	*Depreſſion or Dip of the viſible Horizon in Minutes.*
1	1
3	2
7	3
12	4
18	5
27	6
35	$6\frac{1}{2}$
40	7
45	$7\frac{1}{2}$
50	8

Theſe Minutes muſt be ſubtracted from the Sun's Altitude, and is the ſecond Correction.

Of REFRACTION.

If a Ray of Light, iſſuing from a luminous Body, falls upon a Medium of different Denſity from that before paſſed through, its Direction will be altered from a right or ſtreight Line, and appear broken or bent inwards towards a Line perpendicular to the Surface on which it fell at the Point of Incidence, if this laſt Medium be more denſe than the former, and *vice verſa*, and conſequently the apparent Place of the Object will be different from the true: Our Atmoſphere then being an elaſtic Fluid, and becoming more and more denſe, the nearer to the Surface of the Earth, by the Preſſure of the uppermoſt, it is evident that a Ray of Light will meet with a different Reſiſtance in every Point of its Paſſage there through, and inſtead of a rectilinear Direction it will form a Curve, and the Object from whence it proceeded will appear to the Eye of the Spectator placed on the Surface of the Earth, in the Direction of a Tangent to that Curve in the Point of Incidence; that is, the apparent Place of the Object will be more elevated above the Horizon than the true; whence it follows that the Quantity of the Refraction muſt always be ſubtracted from the Altitude of the heavenly Object, but added to the Zenith Diſtance, and this makes the third Correction.

Of NONIUS's *or rather* VERNIER's DIVISIONS.

The Diviſions on the Limb of ſome of theſe Quadrants are diagonally divided like the common Sea or *Davis*'s Quadrant, the Uſe of which is too well known to need Deſcription; but this Method is not ſo accurate as that called the *Nonius* or *Vernier*'s Diviſion, by which the Poſition of the Index may be known to a ſingle Minute. In Quadrants divided after this Manner,

ner, there is a Scale of Diviſions graduated on the chamfered or ſloped Side of the Index, which Scale is called the *Vernier*; ſee V R, *Fig.* 1 *and* 2. in *Plate* 1. The Principle upon which this Diviſion is founded, is, That in two equal Lines A and B, each conſiſting of the ſame Number of primary Diviſions, if they be again divided into any Number of equal Parts, provided the Number of ſecondary Parts in A be one more than the ſecondary Parts in B; then will one of the latter Parts of B exceed one of the latter Parts of A, by ſuch a Part of A, as will be expreſſed by dividing the Number of the primary in one, by the Product of the Numbers of the ſecondary Parts in both A and B.

Thus if the Length of two Arches A and B be each equal to ſeven Degrees; and A be again divided into 21 equal Parts, and B into 20 Parts:

The $\frac{A}{21} \times \frac{B}{20} = \frac{7}{21 \times 20} = \frac{1}{60} =$ one Minute of a Degree, is the Exceſs of one of the ſecondary Diviſions of B, above one of the ſecondary Diviſions of A.

Or,

If the Length of the Arches A and B be each equal to 6 d. 20 m. and A be divided into 20 and B into 19 Parts;

Then $\frac{A}{20} \times \frac{B}{19} = \frac{6\text{d. }20\text{m.}}{20 \times 19} = \frac{1}{60}$, one Minute as before,

Hence the Nature of this accurate Diviſion may be eaſily underſtood; for ſuppoſe the Length of the *Vernier* to be equal to 7 Degrees, which is divided into 20 equal Parts; but the ſame Number of Degrees on the Limb of the Inſtrument are divided into 21 equal Parts, every Degree being divided into three equal Parts; and conſequently the Exceſs of one of the Diviſions on the *Vernier*, above one of thoſe on the Limb, is equal to one Minute of a Degree.

To eſtimate the Degrees and Minutes by the Vernier *Diviſions.*

If the Altitude be an equal Number of Degrees, the principal Line on the *Vernier* will cut thoſe Degrees on the Limb: If it be any Number of Degrees and exactly 20 or 40 Minutes, then will the principle Line cut the firſt or ſecond Diviſion reſpectively: If the Altitude be any Number of Degrees and Minutes, the principal Line will always ſtand between the Diviſions; and one ſingle Diviſion of the *Vernier*, and no other, will coincide with a Diviſion on the Limb; which Number muſt be added to the Degrees, *&c.* pointed out by the principal Line. Thus, if I find that the principal Line ſtand between the Diviſion of 30 Degrees and 20 Minutes, and at the ſame Time the 15th Diviſion on the *Vernier* coincides exactly with a Diviſion on the Limb, the true Altitude will then be 30 d. 15 m. —— Again, ſuppoſe the principal Line to ſtand between the Diviſions of 20 and 40 Minutes, lying between the 35th and 36th Degrees; and at the ſame Time the 12th Diviſion on the *Vernier* ſtands right againſt a Diviſion on the Arch; the true Altitude will then be 35 deg. 32 min.

When it happens that no one Stroke upon the Arch is oppoſite to a ſtroke upon the *Vernier*; then look for that ſingle Part upon the Limb which is in ſuch Mander oppoſed to a ſingle Part upon the *Vernier*, as to exceed it at both Ends equally, and here allow 30 Seconds more.

To know the GOODNESS *of the* GLASSES.

The Glaſſes ought to be perfectly flat, free from Veins, and of an equal Thickneſs, that thereby both their Surfaces may be truly parallel to each other, in Order to have only one reflected Image. The dark Glaſſes ought alſo to be very true; and to know this, when

when you obſerve by the Sun, take Notice whether the Edges of it appear perfectly ſharp, diſtinct and in one, which cannot happen unleſs the Planes of the Glaſſes are perfectly parallel, and they are beſt tried when the Index is near 90 Degrees, for the Error (if any) will then the moſt conſpicuouſly appear.

To take the Sun or Star's Altitude by a fore Obſervation.

The Altitude of any cœleſtial Object, taken by this Inſtrument, is determined (as hath been explained heretofore) by the Inclination of the Planes of the two Glaſſes to each other, when the Objects appear in the Horizon, that is, of the Horizon Glaſs (F) to the large Speculum fixed on the Index at (I) in the fore Obſervation, and of the Horizon Glaſs (B) to the ſaid Speculum in the back. In the fore Obſervation, the double of this Angle of Inclination is the Altitude ſought, and is marked by the Index (D) on the Arch A C, as aforeſaid. In the back Obſervation, double the Difference of this Inclination from a right Angle gives the ſame Altitude, and is marked by the Index (D) in the ſame Manner; the ſame Scale of Degrees ſerving indifferently for both; ſo that when the Index (D) ſtands at the Beginning of the Scale, as in *Plate* 1. *Fig.* 1. the Surface of the Horizon Glaſs (F) uſed for the fore Obſervation, is exactly parallel to the Surface of the large Mirrour at (I); but the Surface of the Horizon Glaſs (B) uſed for the back Obſervation will then be at right Angles thereunto.

Before the Obſervation is made, great Care muſt be taken to adjuſt the Glaſſes (as before directed) and eſpecially if it be a new Quadrant, or the Wood not well ſeaſoned, for then it will be apt to caſt or warp: Alſo in accurate Obſervations, the line in which the Object is ſeen, muſt be directed parallel to the Plane of the Inſtrument, thro' the reſpective Holes in the Sight Vanes; then hold the Inſtrument as upright as poſſible, with the Arch downwards, the upper Sight Vane being cloſe to the Eye, and the lower Part of the Limb againſt the Obſerver's Breaſt, direct your Sight thro' the tranſparent Part of the oppoſite Horizon Glaſs, to that Part of the Horizon which lies directly under the Sun. Then by moving the Index forwards, bring the Image of the Sun to appear in the Horizon Glaſs, and to deſcend until its lower Edge juſt ſweeps the Horizon: This being done, it will be proper to lean the Inſtrument a little to the right and left, which will cauſe the Sun's Image to ſwing, as it were, in an Arch over the Horizon, and if in thus ſwinging, it appears to dip below the Horizon, the Index muſt be moved backward; if, on the contrary, it appears to fall ſhort of touching, it muſt yet be moved forwards untill its lower Edge bruſhes the ſaid Horizon; then fix the Index in this Poſition, by the Help of a Skrew fixed into a Piece of Braſs on the back Part of the Arch, and the Diviſions on the Face of the ſaid Arch will give the apparent Altitude of the Sun's lower Limb above the viſible Horizon.

In this Caſe the Image of the Sun appears in the ſame Poſition as when ſeen by the naked Eye; but in the back Obſervation the ſaid Image is inverted.—— If the Reflection be too bright for the Eye, turn down one or both of the coloured Glaſſes, as Occaſion requires.

To take the Sun or Star's Altitude by a back Obſervation.

Hold the Octant as before, as upright as you can, with your Back to the Sun, and placing your Eye to the lower Sight Vane, look thro' the tranſpareent Slit in the Glaſs, at the Horizon, and at the ſame Time ſlide the Index until the apparent lower Limb of the Image of the Sun be in Contact with the Edge of the Sea; and there ſkrew the Index faſt; as beforementioned. To know whether the Inſtrument is held upright,

right, keep it and your Arms ſteady, and turn yourſelf ſideways (as it were upon your Heel) to the right and left, and you will ſee the Sun's Image gliding along the Horizon, if the Octant be in a vertical Poſition, and if not, the Sun will deſcribe a Line which croſſes the Edge of the Sea: As to any Motion of the the Inſtrument, as long as the Plane of it continues in the aforeſaid vertical Circle, the Image of the Sun will not (in either Obſervation) be in the leaſt removed thereby from the Edge of the Sea.

The ſame Methods here mentioned and laid down, are alſo to be uſed in taking the Moon's Altitude, but ſhe will not always be bright enough to be ſeen by Reflection in the tranſparent Part of the Horizon Glaſs; and even the Sun itſelf may be ſometimes ſo much obſcured, either by thin Clouds or a Fog, *&c.* that it will be neceſſary to open the lower Hole in the Sight Vane, and view the reflected Image in the ſilvered Part of the Glaſs, which will give a much ſtronger Image while the Horizon is ſeen at the ſame Time thro' the tranſparent Part of the Glaſs, which muſt range in a Line with the Image ſeen in the quickſilvered Part.

Beſides the three Corrections directed to be made, for the Sun's true Altitude, which are likewiſe required in an Obſervation of the Moon, there is a fourth, which is the Moon's Parallax, and which not only varies according to her Altitude, but likewiſe according to her diſtance from the Earth; ſuch therefore, who are unacquainted with aſtronomical Calculations will hereby be rendered incapable of finding the Moon's true Altitude to any great Degree of Exactneſs. However, as it may ſometimes happen that the Moon's Meridian Altitude may be of great Service at Sea, at the End hereof is entered a Table of the Moon's mean Parallaxes according to her Altitude, which are never three Minutes wide of the Truth, and which (I believe) are near enough to be ſometimes of very great Service.

The Moon's Parallax is to be added to her Altitude, beſides the other three Corrections, which are to be uſed in the ſame Manner here as in the Sun's Altitude.

The apparent Diameter of the Moon in the Conjunctions, and in a mean Diſtance from the Earth is 31′ 30″: And the ſame in the Quadratures at a mean Diſtance from the Earth, is 31′ 3″; therefore in round Numbers we may well enough reckon 16 Minutes for her Semidiameter, the ſame as for the Sun.

The ſame Things are to be obſerved in adjuſting the Altitude of a Star; only as a Star has no Diameter, it is evident that the firſt Correction of 16 Minutes, muſt not be uſed, but the other two are neceſſary, as in the Sun's Altitude.

In obſerving by a Star, a different Method muſt be uſed, in Order to bring the Star's reflected Image down to the Horizon: For ſhould the Obſerver look ſtraight at the Horizon, and move the Index forward to bring the Image into the Horizon Glaſs (as is directed for the Sun) he might be very apt to miſs it, or take one Star for another: So that the beſt Way will be to look ſtraight up at the Star, keeping the Index (D) againſt the Button; and if the Glaſſes are truly fixed, the reflected Image of the ſtar will appear co-incident with the Star ſeen by direct Viſion, or in other Words, the ſtar will appear ſingle; but as ſoon as you move the Index forwards, the reflected Image will deſcend below the Star itſelf, which Image muſt be followed by moving the whole Body of the Quadrant downwards, ſo as to keep it in the ſilvered Part of the Horizon Glaſs, as the Motion of the Index depreſſes it, until it comes down exactly on the Edge of the Horizon.

When the Horizon is bright, and the Star faint, it will be more convenient to uſe the back Obſervation; therefore look directly at the Star, and bring the Edge of the Sea to touch the Star by Reflection, the Index (D) will then ſhew (on the Arch AC) the Altitude thereof.

As the Stars can only be made Uſe of by Night, when the Horizon is obſcure, it may be better to get down as low, that is, as near the Horizon as you can, when you make your Obſervation; by this Means you will ſhorten the Horizon: Alſo Obſervations made during Twilight will be preferable.

How to take the SUN'S MERIDIONAL ALTITUDE.

About half an Hour, or rather more, from Noon, prepare for the Obſervation, by fixing and adjuſting your Glaſſes purſuant to the Directions heretofore given for that Purpoſe. When this is done, move the Index (D) forward until the Sun's lower Edge juſt touches the Horizon; keep looking, and obſerve as the Sun's Image riſes, to move the Index ſtill on, in ſuch Manner as to keep it down to the Contact, from Time to Time, till the Sun becomes ſtationary, and as ſoon as ever you obſerve it to fall, the Obſervation is ended, and the Index muſt not be moved any more; therefore here fix the ſaid Index (D) ſecure, by the Help of the braſs Skrew on the back Part of the Arch (AC); Now turn yourſelf about quickly to obſerve the Sun on the back Horizon, and if you ſee the upper Edge of the Sun's Image (which in Fact is the lower Edge) juſt even with the Horizon there, then does your back Obſervation prove right, if not, you muſt rectify it, as before directed; that is, by turning the Horizon Glaſs, not the Index Glaſs, until they coincide, for the Index muſt not be moved; and then reckon what Degrees and Minutes are thereby marked (upon the Arch AC) and ſet them down.

Suppoſe your Altitude to be ——		36°	20′
Firſt Correction, forthe Sun's Semidiameter,	add	0	16
		36	30
Second Correction, for the Dip of the Horizon, your Eye being 27 Feet above the Surface of the Sea.	ſubt.	0	6
		36	30
Third Correction for the Refraction,	ſubtract	0	1
Remains the Sun's true Altitude —		36	29
Subtract the Altitude from ——		90	00
Remains the Sun's Zenith Diſtance —		53	31

Your Index fixed exactly at the Button, and the Horizon Glaſs adjuſted for the back Obſervation, as above directed, which is according to the third Method heretofore propoſed, the three Corrections muſt be allowed preciſely as above.

EXAMPLE II.

In a back Obſervation, when the Index (D) is fixed (for the Adjuſtment of the Horizon Glaſs) beyond the Button, to twice as many Minutes as you allow for the Dip, and the Altitude taken from the Sun's apparent lower Limb, purſuant to the firſt Method,

Suppoſe the Altitude to be ——		20°	10′
1ſt Correction, for the Sun's Semidiameter,	ſubt.	0	16
		19	54
Second Correction for the Dip of the Horizon, the Eye being 50 Feet above the Surface of the Sea	add	0	8
		20	2
Third Correction, for the Refraction,	ſubtract		3
Remains Sun's true Altitude ——		19	59
Subtract the Altitude from ——		90	00
Remains the Sun's Zenith Diſtance ——		70	1

EXAMPLE III.

In a back Obſervation, when the Index (D) is fixed (for the Adjuſtment of the Horizon Glaſs) cloſe to the Button, as for a fore Obſervation, and you take the Altitude from the Sun's apparent lower Limb, purſuant to the ſecond Method,

Suppoſe the Altitude to be	——	29°	30′
1ſt Correction, for the Sun's Semidiameter,	ſubt.	0	16
		29	14
Second Correction, for the Dip of the Horizon, the Eye being 18 feet above the Surface of the Sea	ſubt.	0	5
		29	9
Third Correction, for the Refraction, ſubtract		0	2
Remains the Sun's true Altitude	——	29	7
Subtract the Altitude from	——	90	0
Remains the Sun's Zenith Diſtance	——	60	53

⁂ For the greater Readineſs in working an Obſervation taken by a Star, hereafter is added a Table of the Declination of ſome of the principle Stars.

RULES *for finding the* LATITUDE, *from the* Sun *or* Star's *Zenith Diſtance, and Declination given.*

RULE 1. If the Sun or Star comes to the Meridian in the South, and the Declination be North, then the Declination added to the Zenith Diſtance or Complement of the Meridian Altitude is the Latitude, North.

RULE 2. If the Sun or Star comes to the Meridian in the North, and hath North Declination, then ſubtract the Complement of the Meridian Altitude from the Declination, and the Remainder is the Latitude, North: But if the Complement of the Altitude exceeds the Declination, ſubtract the Declination therefrom, and the Remainder is the Latitude, South.

RULE 3. If the Sun or Star comes to the Meridian in the North, and hath South Declination, the Declination added to the Complement of the Altitude, is the Latitude, South.

RULE 4. If the Sun or Star comes to the Meridian in the South, and hath South Declination, ſubtract the Complement of the Meridian Altitude from the Declination, the Remainder is the Latitude, South: But if the Complement of the Meridian Altitude exceeds the Declination, ſubtract the Declination therefrom, and the Remainder is the Latitude, North.

RULE 5. If the Sun or Star be in the Zenith (that is, right over head) and has either North or South Declination, that Declination is the Latitude either North or South, agreeable to the Name.

RULE 6. If the Sun or Star hath no Declination, the Complement of the Meridian Altitude is the Latitude, and is either North or South, according as the Ship is to the Northward or Southward of the Sun.

RULES *for finding the* LATITUDE, *from the Meridian Altitude and Declination given.*

RULE 1. If the Meridian Altitude and Declination are of different Denominations, that is, one North, the other South, then add 90 Degrees to the Declination, and from that Sum ſubtract the Meridian Altitude; the Remainder is the Latitude of the ſame Name as the Declination.

RULE 2. If the Meridian Altitude and Declination are of the ſame Denomination, that is, both North, or both South, then add the Declination and Altitude together, and ſubtract that Sum (if leſs) from 90 Degrees, the Remainder will be the Latitude of a contrary Name; but if that Sum exceeds 90 Degrees, the Exceſs will be the Latitude of the ſame Name with the Declination and Altitude.

Mr. FLAMSTEAD's TABLE of Refraction, to be ſubtracted from the *Altitude*, and added to the Zenith Diſtance, found by *Hadley's Octant*, or any other Inſtrument.

Alt.		*Refrac.*		*Alt.*		*Refrac.*		*Alt.*		*Refrac.*	
D.	M.	M.	S.	D.	M.	M.	S.	D.	M.	M.	S.
0	00	33	00	19	00	2	21	43	00	0	52
0	30	26	38	20		2	14	44		0	50
1	00	23	22	21		2	07	45		0	48
1	30	20	17	22		2	01	46		0	46
2	00	17	26	23		1	55	47		0	45
2	30	15	15	24		1	50	48		0	44
3	00	13	23	25		1	45	49		0	42
3	30	11	53	26		1	40	50		0	40
4	00	10	39	27		1	36	51		0	39
4	30	9	38	28		1	31	52		0	38
5	00	8	48	29		1	27	53		0	37
6		7	26	30		1	23	54		0	36
7		6	25	31		1	20	55		0	34
8		5	37	32		1	17	60		0	29
9		5	02	33		1	14	65		0	24
10		4	33	34		1	11	70		0	19
11		4	06	35		1	09	75		0	14
12		3	45	36		1	07	80		0	09
13		3	29	37		1	05	85		0	04
14		3	13	38		1	02	90		0	00
15		3	00	39		1	00				
16		2	48	40		0	58				
17		2	38	41		0	56				
18		2	29	42		0	54				

A TABLE *ſhewing the Magnitude and Declination of the Principal fixed Stars.*

	Mag.	Declin.
End of Pegaſus's Wing, Algenib	2	$13^{d}\ 51^{m}$N
Pole Star	2	88 01 N
Girdle of Andromeda	2	34 19 N
Bright Star in Aries	2	22 19 N
Meduſa's Head, Algol	2	40 00 N
Bright Side of Perſeus	2	48 59 N
Aldebaran, or Bull's Eye	1	16 00 N
Capella, or the Goat	1	45 44 N
Bright Foot of Orion, Rigel	1	8 30 S
Middle Star in Orion's Belt	3	1 23 S
Orion's right Shoulder	1	7 21 N
Auriga's right Shoulder	2	44 54 N
Bright Foot of Gemini	2	16 35 N
Syrius, or the great Dog	1	16 24 S
Caſtor, or the Northermoſt Twin	2	32 23 N
Procyon, or the little Dog	2	5 49 N
Pollux, or Southermoſt Twin	2	28 35 N
Hydra's Heart	1	7 38 S
Lion's Heart, or Regulus	1	13 8 N
The lower of the Pointers	2	57 42 N
The upper of the Pointers	2	63 3 N
Lion's Tail, Deneb	1	15 54 N
Upper of the two laſt in the Square of the great Bear	2	58 23 N
Laſt but two in the great Bear's Tail	2	57 18 N
Virgin's Spike	1	9 54 S
Laſt but one in the great Bear's Tail	2	56 13 N
Laſt in the great Bear's Tail	2	50 33 N
Arcturus	1	20 26 N
South Balance	2	15 2 S
Foremoſt Guard	2	75 10 N
Brighteſt of the Crown	2	27 32 N
Brighteſt of the Serpent's Neck	2	7 11 N

	Mag.	Declin.
Antares, the Scorpion's Heart	1	25^d 53^{m}S
Head of Hercules	3	14 40 N
Ophiucus, or Serpent'sHead	3	12 45 N
Lyra, or the Harp	1	38 34 N
Swan's Bill	3	27 29 N
Vulture, or Eagle's Heart	2	8 15 N
Swan's Tail	2	44 26 N
Mouth of Pegaſus	3	8 47 N
Fomelhaut	1	30 53 S
Marchab, or Pegaſus's Wing	2	13 55 N
Scheat, or Pegaſſus's Leg	2	26 45 N
Cepheus's Knee	3	76 7 N
Andromeda's Head	2	27 45 N
Southermoſt in the Whale's Tail	2	19 20 S
Firſt in Orion's Girdle	2	0 29 S
Third in Orion's Girdle	2	2 5 S
North Balance	2	8 28 S
In the Shoulder of the Centaur	2	34 39 S
The Hand of Antinous	3	1 34 S
The upper Horn of Capricorn	3	13 17 S
The lower Horn of ditto	3	15 34 S
Brighteſt in the Tail of Capricorn	3	17 16 S
The preceeding of the two middlemoſt in the Croſs of the Croſiers	3	57 15 S
The Southern Foot of the Croſs	2	61 31 S
The Northermoſt of the four in the Croſiers	2	55 30 S
The Eaſtermoſt of the four in ditto	2	58 6 S

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Middle Star in Orion's Belt	3	1 23 S
Orion's right Shoulder	1	7 21 N
Auriga's right Shoulder	2	44 54 N
Bright Foot of Gemini	2	16 35 N
Syrius, or the great Dog	1	16 24 S
Caſtor, or the Northermoſt Twin	2	32 23 N
Procyon, or the little Dog	2	5 49 N
Pollux, or Southermoſt Twin	2	28 35 N
Hydra's Heart	1	7 38 S
Lion's Heart, or Regulus	1	13 8 N
The lower of the Pointers	2	57 42 N
The upper of the Pointers	2	63 3 N
Lion's Tail, Deneb	1	15 54 N
Upper of the two laſt in the Square of the great Bear	2	58 23 N
Laſt but two in the great Bear's Tail	2	57 18 N
Virgin's Spike	1	9 54 S
Laſt but one in the great Bear's Tail	2	56 13 N
Laſt in the great Bear's Tail	2	50 33 N
Arcturus	1	20 26 N
South Balance	2	15 2 S
Foremoſt Guard	2	75 10 N
Brighteſt of the Crown	2	27 32 N
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	Mag.	Declin.		
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Head of Hercules	3	14	40	N
Ophiucus, or Serpent'sHead	3	12	45	N
Lyra, or the Harp	1	38	34	N
Swan's Bill	3	27	29	N
Vulture, or Eagle's Heart	2	8	15	N
Swan's Tail	2	44	26	N
Mouth of Pegaſus	3	8	47	N
Fomelhaut	1	30	53	S
Marchab, or Pegaſus's Wing	2	13	55	N
Scheat, or Pegaſſus's Leg	2	26	45	N
Cepheus's Knee	3	76	7	N
Andromeda's Head	2	27	45	N
Southermoſt in the Whale's Tail	2	19	20	S
Firſt in Orion's Girdle	2	0	29	S
Third in Orion's Girdle	2	2	5	S
North Balance	2	8	28	S
In the Shoulder of the Centaur	2	34	39	S
The Hand of Antinous	3	1	34	S
The upper Horn of Capricorn	3	13	17	S
The lower Horn of ditto	3	15	34	S
Brighteſt in the Tail of Capricorn	3	17	16	S
The preceeding of the two middlemoſt in the Croſs of the Croſiers	3	57	15	S
The Southern Foot of the Croſs	2	61	31	S
The Northermoſt of the four in the Croſiers	2	55	30	S
The Eaſtermoſt of the four in ditto	2	58	6	S

A TABLE *of the Moon's Mean Parallaxes to be added to her Altitude.*

Alt.	Par.	Alt.	Par.	Alt.	Par.
Deg.	Min.	Deg.	Min.	Deg.	Min.
1	58	31	50	61	28
2	58	32	49	62	27
3	58	33	49	63	26
4	58	34	48	64	25
5	58	35	48	65	25
6	58	36	47	66	24
7	58	37	47	67	23
8	58	38	46	68	22
9	58	39	45	69	21
10	57	40	45	70	20
11	57	41	44	71	19
12	57	42	44	72	18
13	57	43	43	73	17
14	57	44	42	74	16
15	56	45	41	75	15
16	56	46	40	76	14
17	56	47	40	77	13
18	56	48	39	78	12
19	55	49	38	79	11
20	55	50	37	80	10
21	55	51	37	81	9
22	54	52	36	82	8
23	54	53	35	83	7
24	53	54	34	84	6
25	53	55	33	85	5
26	52	56	32	86	4
27	52	57	32	87	3
28	51	58	31	88	2
29	51	59	30	89	1
30	50	60	29	90	0

F I N I S.

Plate 1.

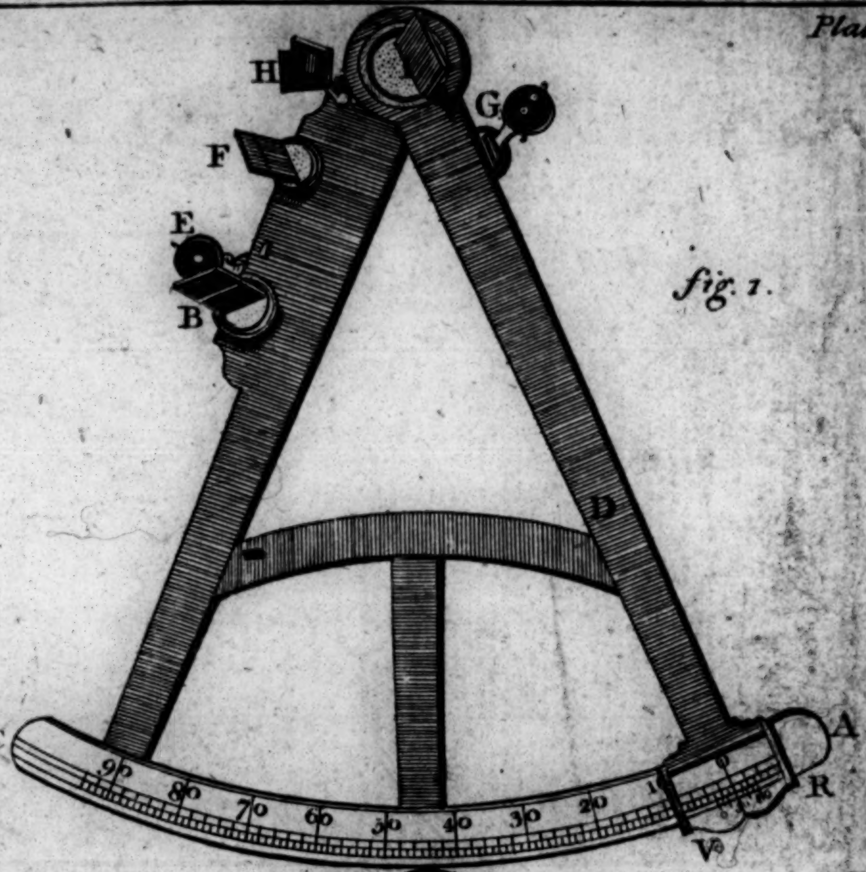

fig. 1.

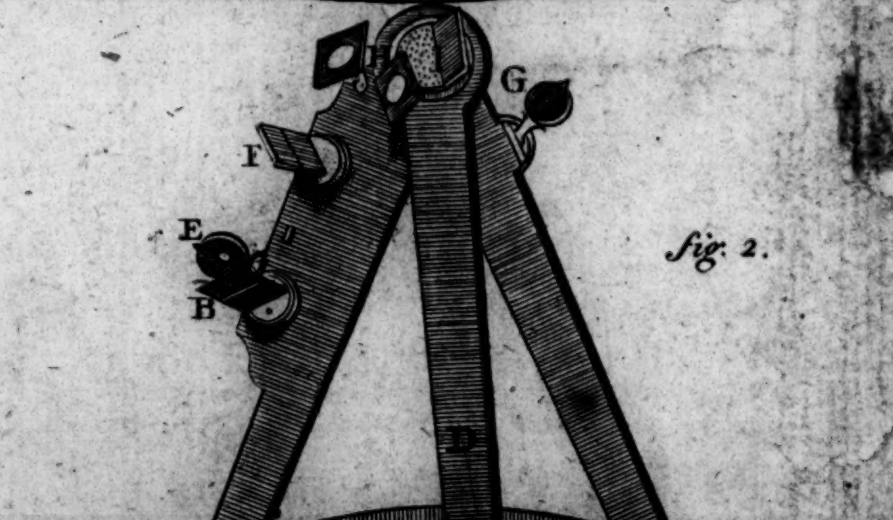

fig. 2.

Plate.

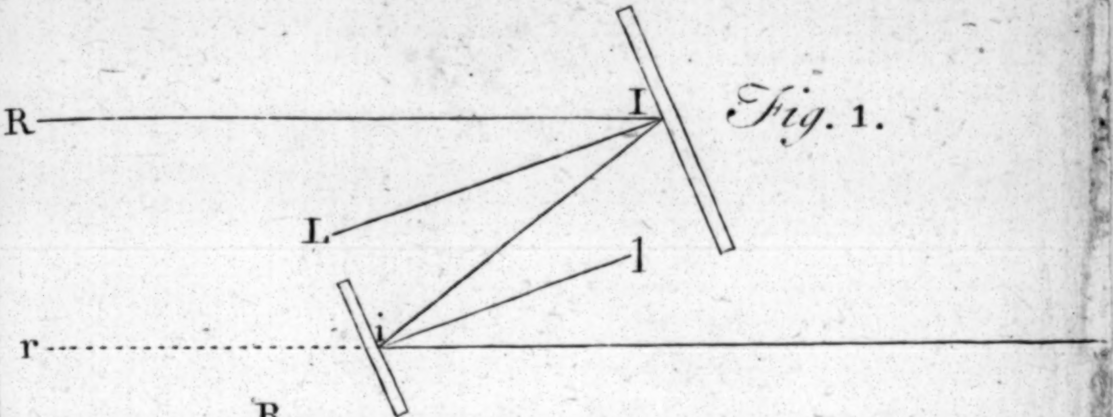

Fig. 1.

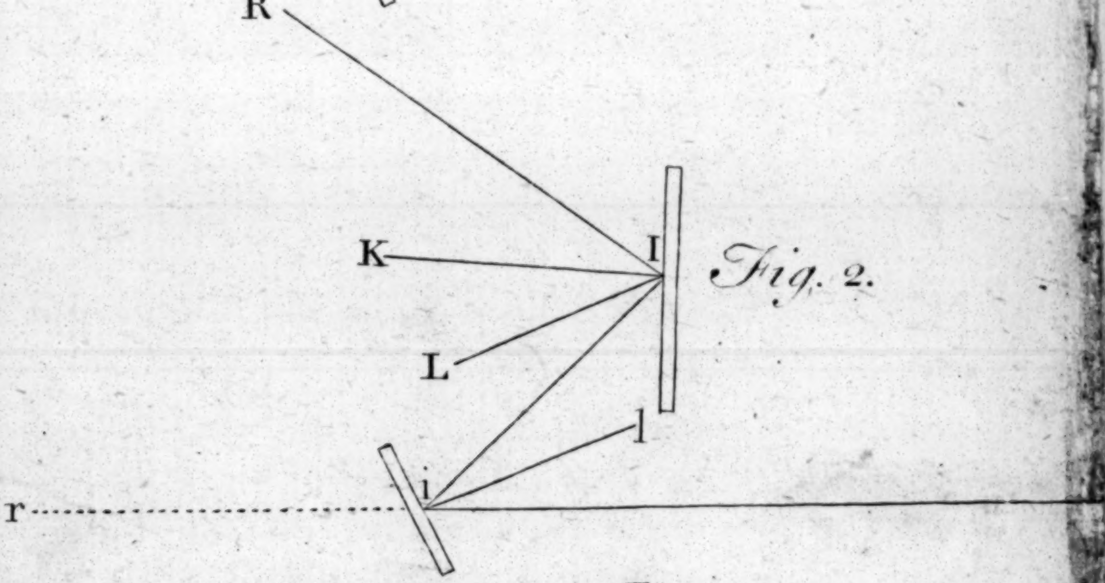

Fig. 2.

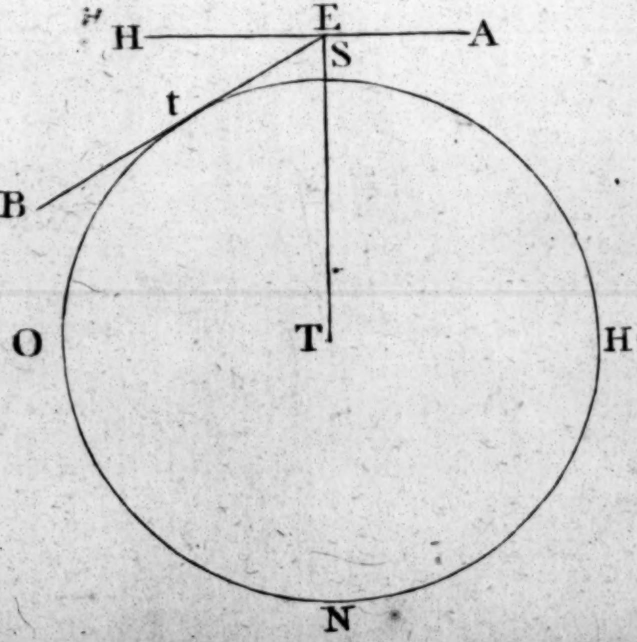

Fig. 3